Report Documentation Page

Form Approved
OMB No. 0704-0188

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1. REPORT DATE **2006**	2. REPORT TYPE	3. DATES COVERED **00-00-2006 to 00-00-2006**

4. TITLE AND SUBTITLE **Architecture-Based Systems Engineering**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Department of Defense,Test Resource Management Center,1225 S. Clark St., Ste. 1200,Arlington,VA,22202**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**2**	

Architecture-Based Systems Engineering

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Test and evaluation (T&E) assets—instrumentation, hardware-in-the-loop facilities, processing software, simulations and more—have been developed over the years to meet a wide variety of needs and requirements. Generally, each of these assets has been developed by using standard systems engineering processes, in which requirements are analyzed, a design is created, hardware and software are manufactured and integrated, and the resulting asset is tested. Such a process results in superb, but limited, point solutions to recognized problems and does not usually result in a solution that might have applicability to more global T&E needs. The achievement of these higher-level goals requires a modification to the standard systems engineering process by creating an *architecture* as the central aspect of the requirements and design process.

An architecture is a *segmentation* of a system (or system-of-systems) such that the primary pieces are identified and their purpose, function, interfaces, interrelatedness and guidelines for their evolution over time are defined. Architectures put constraints on designers and developers. These constraints make possible the achievement of higher-level goals that would not automatically be achieved if developers worked independently. These higher-level goals are called the system's *driving requirements.* A system may have hundreds or thousands of individual requirements; however, the *driving requirements* are those overarching requirements upon which the purpose of the system depends. Once these requirements are identified, it is a relatively straightforward process to segment the system and address these requirements. The architecture is then used as a starting point for a design to fulfill all of the numerous detailed requirements.

An architecture is thus *a bridge from requirements to design,* in which the most important, critical or abstract requirements are used to determine a basic segmentation of the system. An architecture has costs (the constraints) and benefits (the achievement of the driving requirements and the facilitating of the system design). A good architecture is one that achieves the driving requirements using the minimum number of constraints (that is, at minimum cost). It is important to note that *all* systems have architectures, even if they are unstated. The issue is whether an explicit architecture is defined for a system to ensure that its driving requirements are met.

In addition to ensuring that a system can meet broad goals, an architecture also focuses attention on those areas of technological immaturity that prevent the full achievement of the driving requirements. Thus, the architecture can vividly identify the "long poles in the tent" that require science and technology investment. Current efforts to develop non-intrusive instrumentation have relied on architecture development as the core tool for identifying technology shortfalls. This has led to research into advanced "smart" sensors that will be self-calibrating and will not rely on the test article for power or communications. Such non-intrusive sensors will allow testing of advanced weapon systems without the need to heavily modify the test article to install instrumentation systems. Without an overall architecture, each new technology development would focus on a single "point solution" with little relationship to other assets or the broad Department of Defense (DoD) and range community goals and strategies. With an architecture, each new system can address a piece of the whole puzzle rather than simply addressing individual issues out of context.

While architecture-based development has gradually taken a more prominent role in DoD design practice, there is little agreement in the general engineering community over the actual definition of an architecture. The Institute of Electrical and Electronics Engineers gives general guidelines on what an architecture is, and in the software engineering field, the principals of Rational Software Corporation (now owned by IBM) have done a significant amount of work defining a "Rational Unified Process for Systems Engineering" in which to discuss software architectures. The Reference Model for Open Distributed Processing (RM-ODP) is another attempt at describing architectures in a systematic way. However, industry acceptance has been slow in coming.

In an effort to promote interoperability and cost-effective development of software systems, the Defense Science Board in the early 1990s suggested that DoD establish architectural guidance for all DoD military systems. This initiative has culminated in the creation of the DoD Architecture Framework (DoDAF), a guide for system architects to document an architecture in a standard way so that architectures can be compared and contrasted. The DoDAF lists a number of views, each one focusing on a particular aspect of the architecture *(see Figure 1)*.

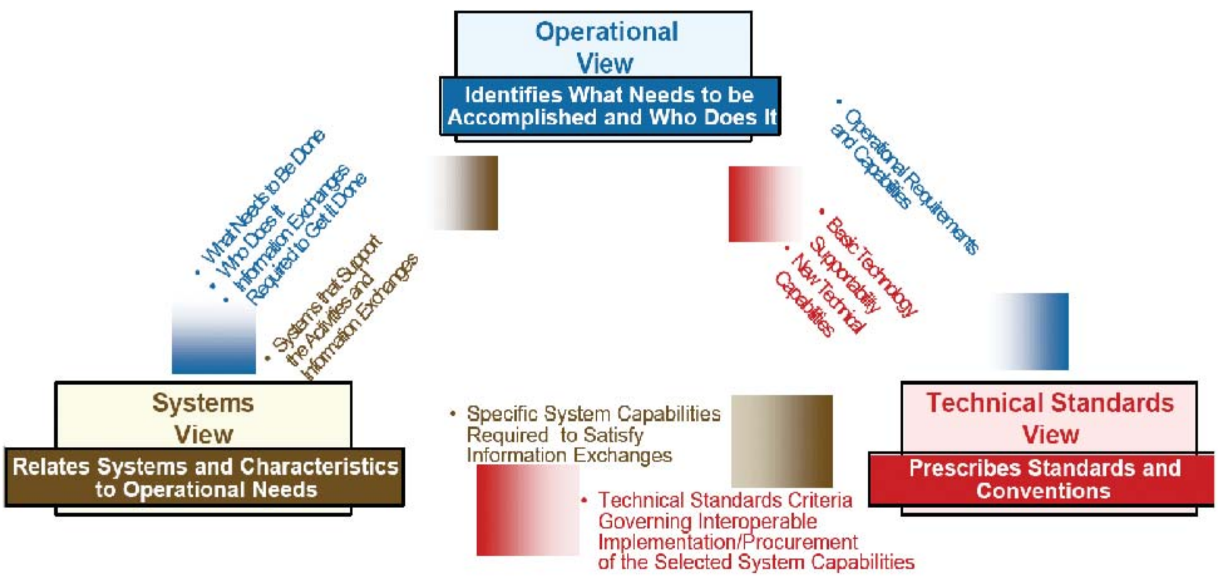

Figure 1. DoD Architecture Framework (DoDAF)

The Office of the Secretary of Defense (OSD) has taken the lead for creating an overall architecture for T&E assets. Each new T&E project is being asked not only to create an architecture for that specific project's deliverables, but also to address how those deliverables would fit into an overall T&E integrated architecture. Among the integrated architecture's driving requirements are interoperability among assets, reusability across ranges and services, spectrum efficiency and enablement of net-centric testing. The first step in T&E architecture-based development was the creation and widespread deployment of the Test and Training Enabling Architecture (TENA), which was designed to enable interoperability and reuse among range software systems. Additional architecture-based development is ongoing under the auspices of OSD, such as the Integrated Network-Enhanced Telemetry (iNET) project, the Data Management project, the T&E for Directed Energy project and others. The end goal of OSD's commitment to architecture-based development is the creation of new T&E assets that not only fulfill their narrow purposes but also fit into an interoperable, DoD-wide common range infrastructure for the next 30 years. ❑

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